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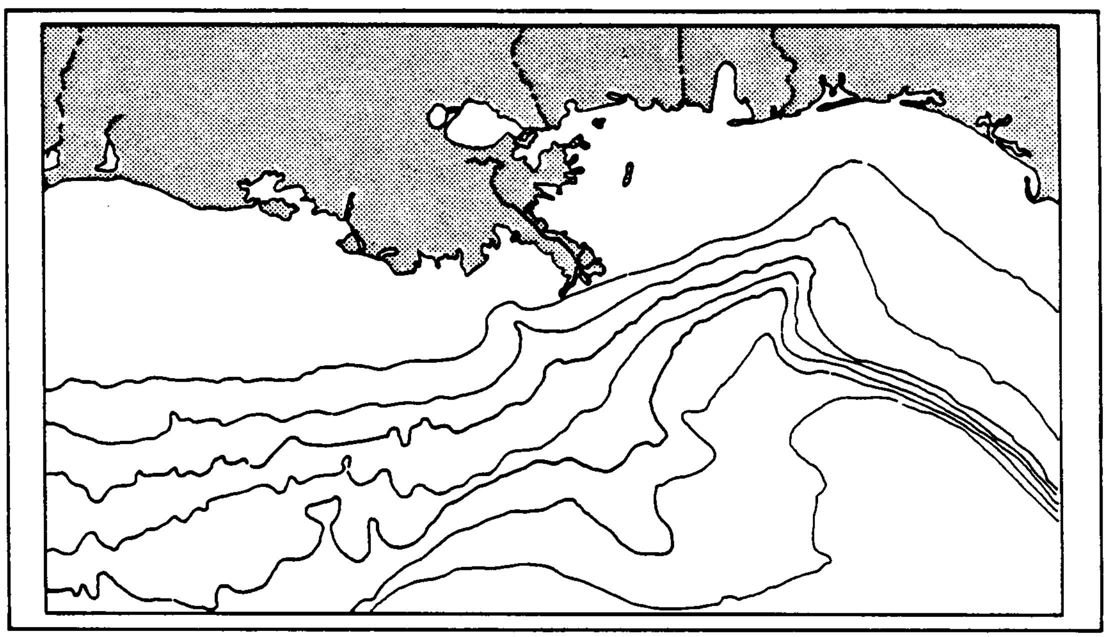
MMS 86-0089

# Gulf of Mexico Continental Slope Study Annual Report Year 2

## Volume I: Executive Summary



MMS
U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Regional Office

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# Gulf of Mexico Continental Slope Study Annual Report Year 2

# Volume I: Executive Summary

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# INTRODUCTION

## STUDY PLAN

This report summarizes the data management and scientific analyses accomplished during the first two years of a multiyear joint LGL Ecological Research Associates/Texas A&M University study of the continental slope of the northern Gulf of Mexico, which was initiated in 1983 by the Gulf of Mexico Regional Office of Minerals Management Service (MMS). The study when completed will be based upon five cruises, all of which were accomplished in the first two years, but the present report, contains data on only the first three cruises. As was built into the original work plan, the results derived from all five cruises will be incorporated into the ensuing Annual Report scheduled for completion in February of 1987. In the fourth and final year a comprehensive data analysis, concept development, and ecological synthesis effort will be accomplished and will serve as the basis for a report that will meet all program objectives.

## STUDY OBJECTIVES

The original delineation of objectives established for the project was compatible with the environmental responsibility of MMS to control, in the Gulf of Mexico, the development of hydrocarbons in time and space within the geographic purview of the Regional Office. Clearly, to do this the Service would have to gain knowledge of what biological and other valuable resources are present on the slope and thus are vulnerable to inevitable impacts of petroleum development. Also, in order to assess the relative significance of various impacts, it would be necessary to understand the ecological processes controlling the welfare of the biota. Hence, in addition to seeing the need for developing a basic knowledge of the components of the deep Gulf fauna, MMS foresaw the importance of investigating the physico-chemical characteristics of the slope and the waters that bathe it, particularly in regard to correlations between their variable characteristics and responsive difference in the biota, both in time and place. It is evident that unless one can circumscribe natural variations in biotic assemblages, there is a high probability that such changes will be ascribed to impacts associated with oil and gas production on the slope. LGL's statistical treatment of population data will be mindful of this issue.

## SAMPLING TRANSECTS

Sampling during the cruises has been organized on three transects, one each in the MMS Western, Central, and Eastern Gulf of Mexico Lease Planning Areas (Fig. 1). Cruises have been carried out to examine possible effects of seasonal changes, and stations have been located on the transects in a sequence of increasing depth to investigate bathymetric influences. Thus, Cruise I (November 1983), sampled only the Central Transect at five stations (depths of 329, 786, 850, 1440, and 2450 m); in Cruise II (April 1984), these Central stations were sampled, and five stations were sampled on the Western Transect at 342, 653, 828, 1413, and 2314 m depths, and five on the Eastern Transect at depths of 367, 622, 828, 1172, and 2857 m. Whereas for these two cruises stations were located in previously suggested faunal zones (Pequegnat 1983)*, discussions in the Science Advisory Committee advised that the scheme of zonation might be an artifact related purely to sampling depth and might not therefore be a valid representation of the actual distribution of faunal assemblages. As a result during Cruise III (November 1984) 12 stations were sampled, all on the Central Transect, at seven intervening depths as well as the original five (Fig. 1). Considerable effort was expended in gathering data at these depths not only on the fauna but also on such factors as sediment texture, waster masses, temperature, and salinity that could play some role in physical and biotic zonation.

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*Shelf/Slope Transition Zone: depths between 150-450 or so m;
Archibenthal Zone - Horizon A: 475-750 m;
- Horizon B: 775-950 or so m;
Upper Abyssal Zone: 975-2250 or so m;
Mesoabyssal Zone - Horizon C: 2275-2700 or so m.

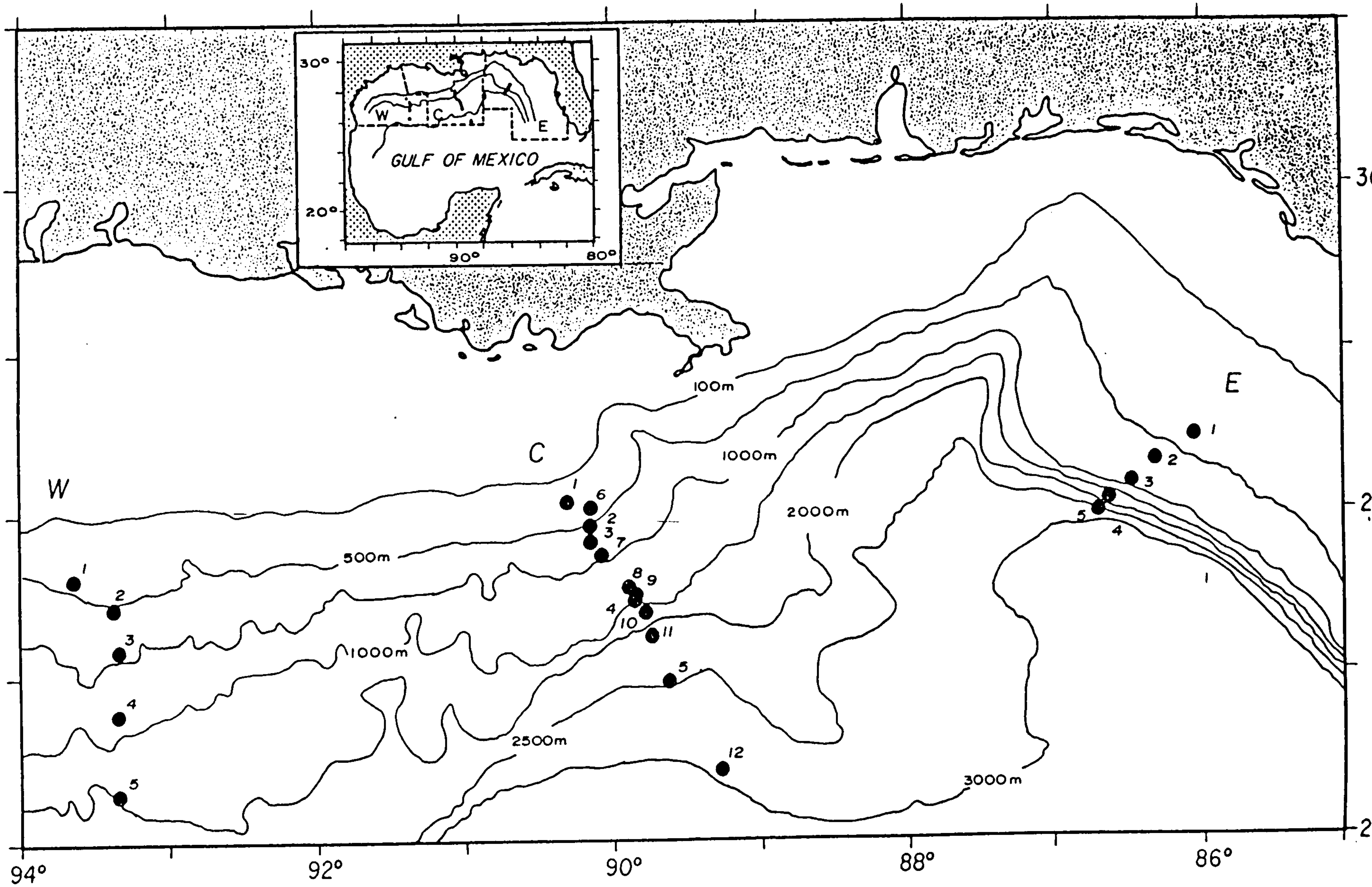


Figure 1. Sampling locations for Cruises I-III.

## PHYSICAL AND CHEMICAL PROCESSES

### WATER COLUMN STRUCTURE

Results of the hydrographic measurements of temperature, salinity, dissolved oxygen, $NH_4$, $NO_3$, $NO_2$, silica, and POC at all station depths for all five cruises are shown in Appendix B-1 of the Appendix Volume. Defined by some or all of these parameters, the three layering water masses expected at the sampling stations each met expectations and were identified in part by the following:

Tropical Atlantic Central Water - oxygen minimum
Antarctic Intermediate Water - nitrate maximum
- phosphate maximum
- salinity minimum
Caribbean Water - silicate maximum
Gulf Deep Water

The Tropical Atlantic Water (300-500 m) bathes the Shelf/Slope Transition; the Antarctic Intermediate Water (500-1000 m) spans the Archibenthal Zone; the Upper Abyssal Zone is exposed to the Caribbean Water (1000-1650 m); and the Mesoabyssal Zone is covered by the Gulf Deep Water (1650 to the bottom of the basin at 3850 m). Although the thermometric lowest temperature of about 4.19°C is reached at 2000 m, it rises about 0.1°C per 1000 m increase in depth to the bottom (adiabatic warming). However, the potential temperature at the bottom is therefore actually below 4°C. At 2000 m the salinity is about 34.97 ppt but it also rises about 0.002 ppt per 1000 m.

### SEDIMENT HYDROCARBONS

HYDROCARBONS - SEDIMENTS

Sediments on the continental slope of the Gulf of Mexico contain a mixture of terrestrial, planktonic, and petrogenic hydrocarbons. A comparison of the concentrations of hydrocarbons found in slope sediments shows them to be generally lower than reported values for the Gulf, but these latter baseline values were derived primarily from analysis of coastal and shelf sediments. In general, the qualitative molecular-level alkane distribution was similar at all sites sampled. While the dominant normal alkane between $n\text{-}C_{15}$ and $n\text{-}C_{22}$ was variable, the dominants between $n\text{-}C_{23}$ and $n\text{-}C_{32}$ were consistently either $n\text{-}C_{29}$ or $n\text{-}C_{32}$.

HYDROCARBONS - ORGANISMS

Hydrocarbon concentrations in megafaunal invertebrates and demersal fishes of the Gulf slope are highly variable (details in Appendices B-7, 8, and 9). No trends in hydrocarbon distributions were found as a function of the type of organism; at least among shrimp, crabs, and fish. Among these, crabs and shrimps had the lowest incidence of hydrocarbon occurrence in muscle (60% hydrocarbon free), and fish the highest with only 21% free of hydrocarbons.

Tissue hydrocarbons were generally dominated by pristine, $n\text{-}C_{17}$, $n\text{-}C_{15}$, and $n\text{-}C_{19}$, which are predominantly of planktonic origin. Although $n\text{-}C_{16}$, $n\text{-}C_{18}$, and phytane were present in low concentrations, their source could be from petroleum or bacteria. The presence in some organisms of the Central Transect of plant biowax hydrocarbons, which are thought to reside in sediments and not in the water column, suggest that these organisms either ingested sediments or some sediment-feeding prey. Highest concentrations of alkanes were found in the gonads and liver; however, lesser amounts were consistently found in muscle tissue as well.

HYDROCARBON SOURCES

There are some assumptions that guide the search for specific sources of the hydrocarbons found in the sediments of the continental slope of the northern Gulf of Mexico. Three major sources are delineated, viz., (1) plankton input which is estimated as the sum of $n\text{-}C_{15}$, $n\text{-}C_{17}$, $n\text{-}C_{19}$, and pristane minus the sum of $n\text{-}C_{16}$, $n\text{-}C_{18}$, $n\text{-}C_{20}$, and phytane (or, in other words the plankton source minus a petroleum source); (2) the terrestrial input from the sum of plant straight-chain biowaxes $n\text{-}C_{25}$, $n\text{-}C_{27}$, $n\text{-}C_{29}$, and $n\text{-}C_{31}$ minus the petroleum-derived $n\text{-}C_{24}$, $n\text{-}C_{26}$, $n\text{-}C_{28}$, and $n\text{-}C_{30}$; and

(3) the petroleum input which is the sum of all of the above even numbered alkanes.

Other considerations that are useful in understanding the flux of hydrocarbons in the slope sediments are the unresolved-complex-mixture, which is directly related to petroleum inputs; the carbon preference index, which is the ratio between the biogenic and petroleum inputs; and bulk sediment characteristics.

## VARIATIONS IN DISTRIBUTION IN SPACE AND TIME

### Areal Distribution

Extractable organic matter (EOM) is a composite of material derived from both biogenic and petroleum sources. EOM concentrations were lowest on the Eastern Transect and except for Station W1 were about equal on the Western and Central Transects (Fig. 2). The elevated EOM at W1 is due to an increase in the petroleum component.

The amount of terrestrial hydrocarbons decreased from a high on the Central Transect (about twice the others) to lows on both the Western and Eastern Transects.

Sediment biogenic hydrocarbons on the slope were dominated by the more resistant terrestrial components, and the degree of dominance was a function of proximity to the influence of the Mississippi River. Planktonic inputs were low on the Central and Western Transects, perhaps as a result of high sedimentation rates or dilution with riverine material. This input was more easily discerned on the Eastern Transect probably because of a lesser riverine input.

In general, petroleum input was greatest on the Central Transect, but all values on all transects were relatively low. The documentation of extensive natural hydrocarbon seepage on the continental slope suggests that this process is a major source of petroleum hydrocarbons in the sediments of the Central and Western Transects in particular.

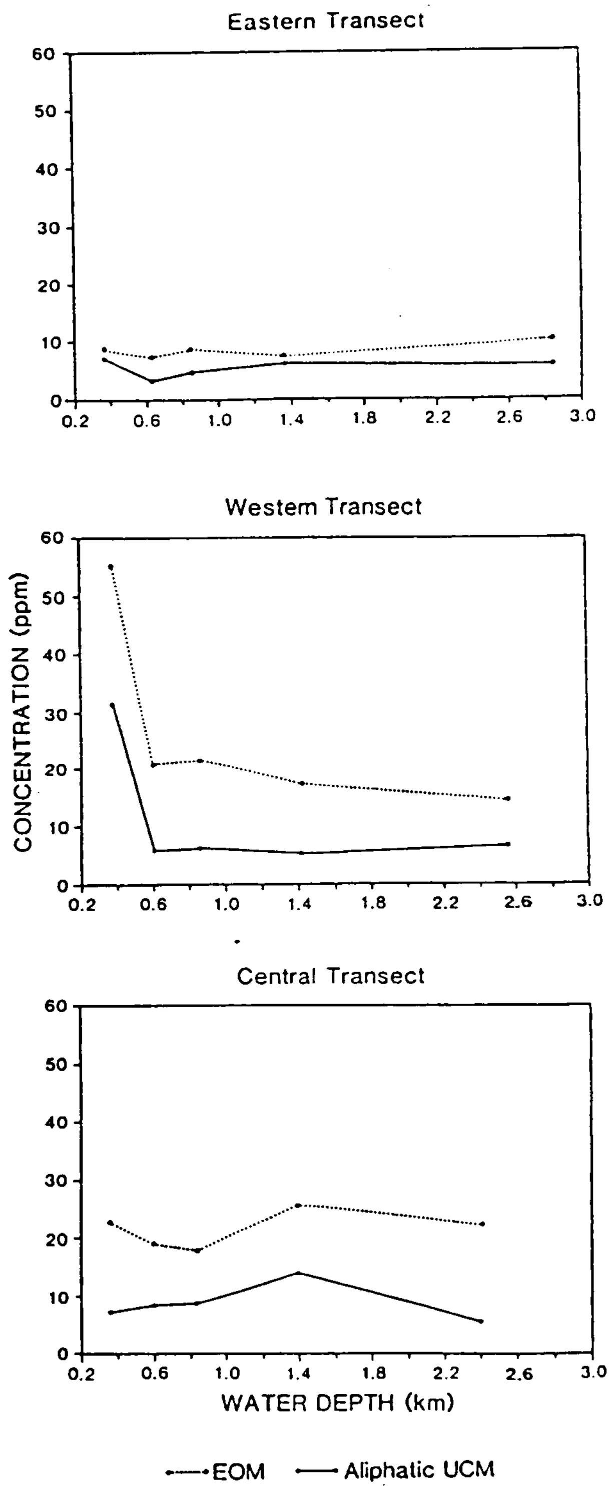


Figure 2. Variation in extractable organic matter and the aliphatic unresolved complex mixture along transects in the eastern, western, and central Gulf of Mexico continental slope.

Distribution Variations with Time

It has not been possible to document that any changes noted in concentrations of petroleum hydrocarbons in the sediments during the three cruises were related to temporal phenomena. It is much more likely a reflection of the patchiness of hydrocarbon distribution and thus of chance in the sampling process.

Distribution Variations Along Isobaths

Measurements along three isobaths during Cruise V to assess lateral variations in hydrocarbon concentrations revealed that they are as variable along isobaths as they are with water depth. This not only supports the concept of the patchy hydrocarbon distribution but also reveals a parallel with variations observed in sediment texture.

Relationship to Bulk Sediment Parameters

Generally, the highest aliphatic hydrocarbon concentrations were found in clay sediments rich in organic carbons. The correlation of the terrigenous source indicator with grain size supports the premise that these n-alkanes represent riverine or land-derived material. The petroleum indicators were generally independent of grain size. Phytoplankton-derived hydrocarbons did not correlate with grain size at all.

CARBON ISOTOPES

CHEMOSYNTHETIC ECOSYSTEMS

Initial measurements made on northern Gulf slope and seep organisms show that all the vent-type taxa (bivalves, tubeworms and gastropods) are isotopically light (-27 to -37 $^{o}/_{oo}$) compared to other benthic slope organisms (crabs, shrimps) that derive their carbon from photosynthetic carbon. These light values are similar to the -32 to -34 $^{o}/_{oo}$ $\delta^{13}C$ values reported for the Pacific hydrothermal vent communities. At the Louisiana seep ecosystems the $\delta^{13}C$ of the tubeworm is only slightly heavier (4-7 $^{o}/_{oo}$) than the bivalves and gastropods. One measurement of a tubeworm attached to a carbonate rock ($\delta^{13}CaCO_3$ = -50 $^{o}/_{oo}$) had a $\delta^{13}C$ value of -37 $^{o}/_{oo}$. This is in marked contrast to tubeworm $\delta^{13}C$ values at Pacific spreading centers in which the tubeworm $\delta^{13}C$ values were 20 to 25 $^{o}/_{oo}$ heavier than the mussels. These differences were attributed to chemoautotrophic synthesis occurring symbiotically in the tubeworms. The Louisiana seep tubeworms apparently fix carbon internally with fractionation similar to the bivalves and gastropods. In fact, the final isotopic composition of the tissue may ultimately depend on the carbon isotopic composition of the original carbon source. The isotopically light organisms in the seep regions apparently derive their energy from bacteria that utilize light $CO_2$ either from the bacterial breakdown of oil or from the seeping oil/gas.

## ISOTOPIC COMPOSITION OF ORGANIC MATTER IN SEDIMENTS

Isotopic data confirm the previously inferred influence of river-borne terrigenous material on the Gulf of Mexico. Though there are various complicating factors, in general a more negative carbon isotopic composition suggests greater land influence. Organic matter of terrestrial origin has $\delta^{13}C$ values that vary from -25 to -28 $^{o}/_{oo}$, whereas plankton-derived carbon $\delta^{13}C$ varies from -16 to -21 $^{o}/_{oo}$. The average $\delta^{13}C$ value of sedimentary organic matter is most positive on the Eastern Transect and most negative at the Central and Western sampling sites. This observation suggests an increased influence of planktonic material at the eastern sites, as would be expected.

## ISOTOPIC COMPOSITION OF ORGANISMS

In general we expect an overall pattern of increasing carbon isotope ratios with increasing trophic level from diatoms (-20.3 $^{o}/_{oo}$) to benthic predators (-16.6 $^{o}/_{oo}$). Present data bear this out. Detailed carbon isotope data for organisms collected at each station sampled may be found in Appendix B-3.

## BIOLOGICAL OCEANOGRAPHIC CHARACTERISTICS OF THE NORTHERN GULF

### MEGAFAUNA

#### CRUSTACEA

One hundred and four species of benthic megacrustacea were collected in the trawl along the three transects. Some 85% of the species were decapods (Table 1) and of these the Anomura (hermit crabs and related types) yielded the most species, followed by the Caridea (prawns). An average of 70% of the crustacean species occur at depths in excess of 1000 m--a depth that generally marks the upper limit of the true deep sea. It is interesting to note that in the case of the decapods the average percentage of species in the deep sea for all types except crabs was 54, whereas for the crabs it was only 18. This signifies a low production in the deeper parts of the slope.

#### ECHINODERMATA

Some 84 species of megafaunal species were collected by the trawl from all three sampling transects. Asteroids and ophiuroids accounted for about 70% of all the echinoderms (Table 2). But only 60% of the echinoderm species were collected at depths greater than 1000 m. This is accounted for by the large number of asteroids and ophiuroids that are carnivorous, a situation that parallels the brachyuran distribution among crustaceans. Some 94% of the holothurians occur below 1000 m, an observation to be anticipated in part because they are deposit feeders whose food supply is not so limited by depth conditions.

#### DEMERSAL AND BENTHOPELAGIC FISH

A total of 112 species of demersal or benthopelagic fish has been collected on the three transects by trawling. It has been noted that 32 of the 112 species are represented in the collection by a single individual. This suggests that additional species may well be added to the collection when the results of Cruises IV and V are ready for

Table 1. Megafaunal Crustacea collected by trawl during Cruises I, II, and III of the LGL study.

| Taxa | No. Of Species | % Of All Megacrustacea | No. Of Spp. At Or Below 1000 m | % Of Species Below 1000 m |
|---|---|---|---|---|
| CIRRIPEDIA | 7 | 7 | 4 | 57 |
| ISOPODA | 2 | 2 | 2 | 100 |
| AMPHIPODA | 5 | 5 | 5 | 100 |
| DECAPODA | 89 | 85 | 62 | 70 |
| Penaeidea | 11 | | 6 | 55 |
| Caridea | 24 | | 12 | 50 |
| Anomura | 28 | | 15 | 54 |
| Paguridae | (9) | | 5 | 56 |
| Porcellanidae | (1) | | 0 | 0 |
| Chirostylidae | (2) | | 2 | 100 |
| Lithodidae | (1) | | 1 | 100 |
| Galatheidae | | | | |
| *Munida* | (6) | | 2 | 33 |
| *Munidopsis* | (9) | | 5 | 56 |
| Macrura | 9 | | 5 | 56 |
| Polychelidae | (4) | | 3 | 75 |
| Nephropidae | (3) | | 2 | 66 |
| Scyllaridae | (1) | | 0 | 0 |
| Axiidae | (1) | | 0 | 0 |
| Brachyura | 17 | | 3 | 18 |
| STOMATOPODA | 1 | 1 | 0 | 0 |
| PYCNOGONIDAE (an arachnid) | 1 | | 1 | 100 |
| | 104 Crustacea | 100 | 73 | Ave. 70%. |

Table 2. Number of megafaunal species collected in echinoderm classes and their bathymetric distribution.

| Class | No. of Species | % of all Echinoderm spp. | No. Species Below 1000 m | % of Group Below 1000 m |
|---|---|---|---|---|
| Asteroidea | 28 | 33 | 15 | 54 |
| Ophiuroidea | 30 | 36 | 13 | 43 |
| Echinoidea | 8 | 10 | 5 | 63 |
| Holothuroidea | 16 | 20 | 15 | 94 |
| Crinoidea | 2 | 1 | 2 | 100 |
| | 84 | 100 | 50 | Ave. 60 |

analysis. In spite of the fact that fish are generally quite mobile, it is interesting to note that almost 60% of the fish species are confined to a single zone.

## ADDITIONAL MEGAFAUNAL GROUPS

In addition to the three megafaunal groups noted above, representatives of other phyla were taken in the trawl. A detailed treatment of the station counts for each species can be found in Appendix C-1.

## MEGAFAUNAL ASSEMBLAGES AND ZONATION

It is well known that the megabenthic fauna of the ocean undergoes a compositional change with depth from shore to the abyssal plain. What has not yet been established is simply whether there are discernible separations or demarcations between faunal assemblages along the depth gradient or whether any discontinuities are simply sampling artifacts, the separations between groups appearing on a graph due to the lack of sampling at the point involved. Results to date in the LGL/TAMU study show clearly on the Central Transect that there are greater numbers of species and individuals at predictable reaches of the slope and that these clusters are indeed separated by less dense assemblages (Fig. 3). It is this clustering of assemblages that constitute the essence of the faunal zones.

Although LGL prefers to await the results of analyzing biological data from Cruises IV and V before making definitive specific statements about depths, the general impression gained from the analyses done to date is that there are indeed faunal zones on the continental slope. There appears to be no reason to abandon the assignment of zones found in Pequegnat (1983), but as intimated above it may be advantageous to reassign some depth limits in light of forthcoming data. Of course, the data may equally well demonstrate that depth changes will not be necessary. A brief description of the characterizing faunal assemblages of each zone are given below.

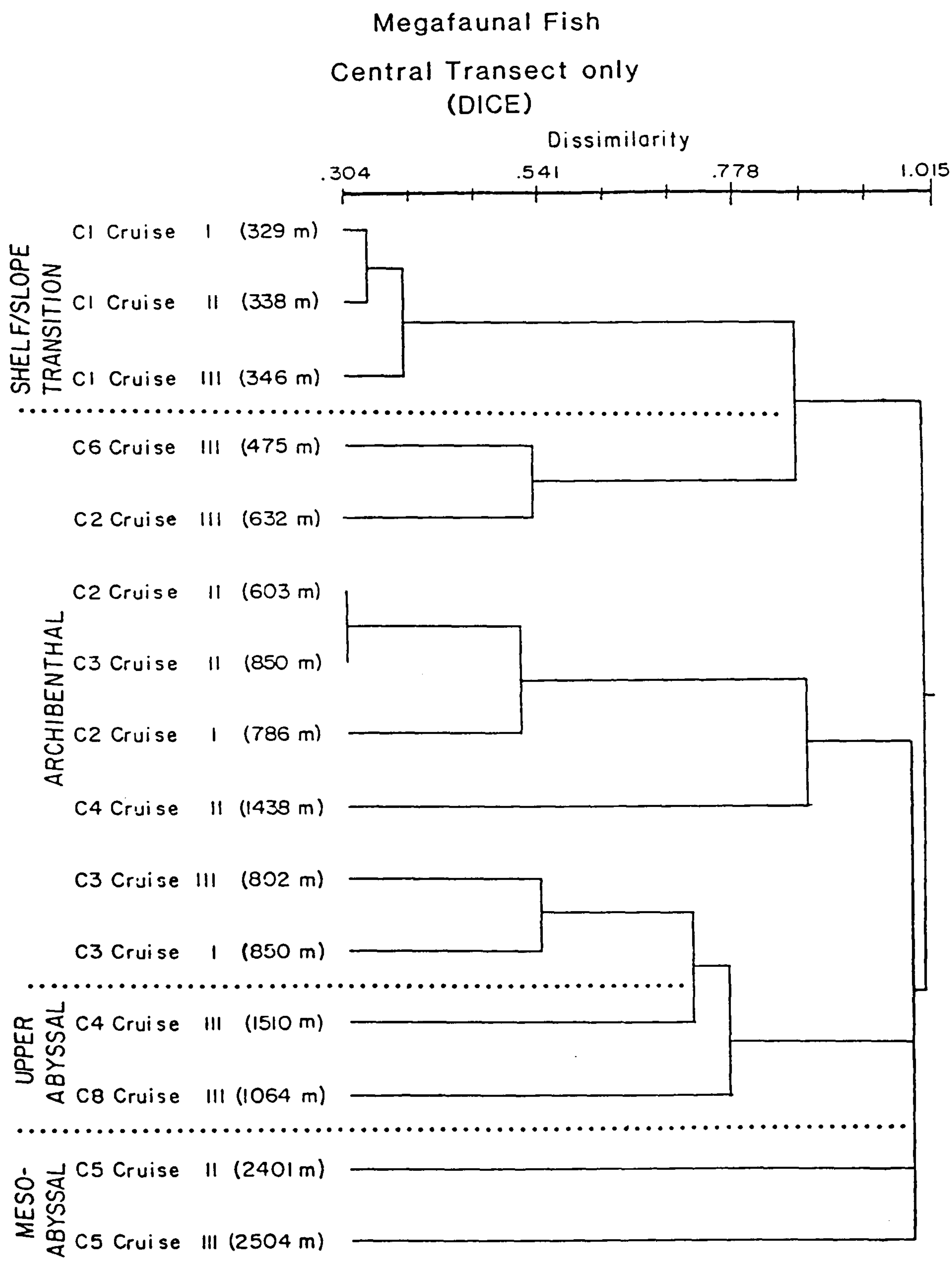


Figure 3. Dendrogram of demersal fish species collected by trawl and clustered on the basis of dissimilarity.

Shelf/Slope Transition Zone (150-450 m)

The shallowest LGL stations (about 330 m) obviously sampled only the bottom third of this zone. Even so, the principal indicator species of the zone were obtained. It is characterized by species that have the center of their populations on the shelf but do penetrate some distance down the slope, as well as by others that have maximum populations on the upper slope but do occur in smaller numbers on the outer shelf. Some 35 species of demersal fish were collected in the zone and 31 of them attain maximum populations in its depth limits. The zone is also characterized by brachyuran crabs and large brissopsid sea-urchins, as well as by the absence of large sea cucumbers. Also, the genus *Munida* far outranks the genus *Munidopsis* among galatheids.

Archibenthal Zone Horizon A (475-750 m)

Demersal fishes are well represented in this horizon of the Archibenthal Zone with a total of 45 species of which 29 have maximum populations here. Nevertheless, the total number of individuals in those species of both fish and megainvertebrates that have maximum populations here drops from 718 in the Shelf/Slope Transition to 604.

Archibenthal Zone Horizon B (775-950 m)

Demersal fishes are still moderately well represented in this horizon with a total of 36 species, but there is a sharp reduction in those that reach maximum populations from 29 species in Horizon A to only 15 in Horizon B. Also, there is a sharp break in the number of individuals in the latter species from 604 in Horizon A to 272 here. These reductions seem to mark a division of the demersal fish fauna into two bathymetric groups, one above and one below. This will become more apparent when it is noted that in the next lower zone the number of species attaining maximum populations rises substantially.

In Horizon B only reduced numbers of brachyuran crabs are present, and the genus *Munidopsis* has virtually replaced *Munida*. The sea cucumbers are much more abundant with the large *Mesothuria lactea* predominating. It should be noted also that the *Brissopsis* sea-urchins have dropped out.

Upper Abyssal Zone (975-2250 m)

The number of species of demersal fishes increases in this zone with a total of 44. Moreover, the number of species that reach maximum populations rises from 15 in Horizon B to 30 here. And, as would be expected, the number of individuals in these species also rises from 273 in Horizon B to 331 in this zone. It is here also that the typical deep-water echinoderm species appear, e.g., the sea-urchins *Plesiodiadema antillarum* and *Phormosoma placenta* and the sea cucumbers *Psychropotes depressa* and *Benthodytes lingua*

Mesoabyssal Zone Horizon C (2275-2700 m)

The number of demersal fishes undergoes a precipitant drop in numbers in this horizon to a total of only five species of which four attain maximum populations here. This parallels the situation found in Pequegnat (1983). Moreover, the number of individuals in these species totals only 12, or about 4% of the numbers in the Upper Abyssal.

MACROFAUNA

The present LGL collections from the three transects contain a minimum of 980 taxa of macrofauna (those held on a 0.3 mm screen) that are or eventually will be designated as species (Table 3). We note, however, that this total does not include some less important groups such as nemerteans, aplacophorans, priapulids and podocopid ostracods that undoubtedly represent a sizable number of species, but were not originally scheduled for identification to the species level.

Seventy percent of the 980 macrofaunal species have their maximum density (no/m$^2$) in the Archibenthal (337 spp.) and Upper Abyssal (336 spp.) zones, followed by 20% in the Shelf/Slope Transition (199 spp.) and 10% (89 spp.) in the Mesoabyssal (Table 3). Note that the Polychaeta has more species than any other group followed by the Tanaidacea and Isopoda.

Table 3. Distribution of macrofaunal species among faunal zones by depth of maximum density. Numbers in parentheses are other species that occur in the zone. Macrofauna collected by means of 0.1 $m^2$ boxcorer.

| | Faunal Zones | | | | |
|---|---|---|---|---|---|
| Taxa | Shelf/Slope Transition (150-450 m) | Archibenthal Zone (475-950 m) | Upper Abyssal (975-2250 m) | Mesoabyssal (2275-3225 m) | Totals Max. Dens. Only |
| Porifera | 0 ( 0) | 3 ( 4) | 17 ( 3) | 11 ( 0) | 31 |
| Coelenterata | 5 ( 2) | 6 ( 2) | 5 ( 2) | 0 ( 0) | 16 |
| Polychaeta | 92 ( 62) | 143 ( 87) | 62 ( 84) | 6 ( 50) | 322 |
| Gastropoda | 10 ( 5) | 6 ( 7) | 8 ( 1) | 0 ( 0) | 24 |
| Bivalvia | 9 ( 11) | 6 ( 16) | 24 ( 5) | 10 ( 9) | 49 |
| Scaphopoda | 1 ( 2) | 0 ( 6) | 6 ( 3) | 3 ( 3) | 10 |
| Myodocopa | 3 ( 2) | 9 ( 4) | 2 ( 6) | 1 ( 1) | 15 |
| Cumacea | 6 ( 12) | 20 ( 15) | 23 ( 11) | 6 ( 4) | 55 |
| Tanaidacea | 10 ( 19) | 53 ( 46) | 63 ( 28) | 21 ( 21) | 147 |
| Isopoda | 11 ( 3) | 24 ( 42) | 51 ( 27) | 14 ( 21) | 100 |
| Amphipoda | 16 ( 13) | 27 ( 20) | 18 ( 15) | 1 ( 6) | 62 |
| Sipuncula | 16 ( 3) | 12 ( 7) | 8 ( 4) | 1 ( 2) | 37 |
| Bryozoa | 14 ( 6) | 22 ( 7) | 24 ( 6) | 10 ( 3) | 70 |
| Brachiopoda | 0 ( 1) | 0 ( 1) | 2 ( 0) | 0 ( 1) | 2 |
| Ascidiacea | 0 ( 0) | 0 ( 2) | 8 ( 0) | 2 ( 1) | 10 |
| Asteroidea | 1 ( 0) | 0 | 1 ( 0) | 0 ( 0) | 2 |
| Ophiuroidea | 4 ( 1) | 4 ( 4) | 5 ( 2) | 3 ( 0) | 16 |
| Echinoidea | 0 ( 1) | 0 ( 2) | 1 ( 1) | 2 ( 1) | 3 |
| Holothuroidea | 1 ( 0) | 2 ( 2) | 6 ( 3) | 0 ( 2) | 9 |
| Crinoidea | 0 ( 0) | 0 ( 0) | 2 ( 0) | 0 ( 0) | 2 |
| MAX. DENSITY TOTALS | 199 | 337 | 336 | 89 | 980* |
| OTHER SPECIES TOTALS | (143) | (274) | (201) | (125) | |
| GRAND TOTALS IN ZONES | 342 | 611 | 537 | 214 | |

*Does not include undetermined species of podocopid ostracods and a few oligochaeta.

In Table 3 we see also that whereas there are more species of polychaetes in the two shallow zones, they are outranked by tanaidaceans in the Upper Abyssal and far outranked by several groups in the Mesoabyssal.

The large number of species in the Tanaidacea (147), Bryozoa (100), and Sipuncula (37) is an unexpected finding. Since many tanaidaceans are carnivorous, they may well feed upon meiofauna.

The distribution of macrofauna among faunal zones is quite interesting. In Table 4 we see that an average of 65% of the species are confined to a single zone. The groups that have the highest percentage of species so confined are Porifera, Coelenterata, Scaphopoda, Bryozoa, Sipuncula, Asteroidea, Crinoidea, and Gastropoda. Those with the lowest percentages of species confined to a single zone are Polychaeta and all crustacean groups except the Tanaidacea.

## MEIOFAUNA

The meiofauna are defined in this report as those infaunal organisms that pass through a 0.3 mm sieve but are retained on a 0.063 mm sieve. Most of the data derived to date from the present study are summarized in Table 5. The following observations can be made at this time:

1. There is generally an orderly decrease of total meiofauna per 10 $cm^2$ as depth increases. There are some irregularities at intermediate depths on the Central Transect in Cruise III, but in no case are the totals of the deepest stations as great as those of the shallowest stations.
2. The Nematoda are the most abundant taxon in the meiofauna. The second most abundant group alternates between the Foraminifera and the Harpacticoida but only on the Central Transect. Otherwise the Harpacticoida are consistently second, followed by nauplii (copepod), Polychaeta, Ostracoda, and Kimorhyncha.
3. The trend of reduction in total meiofauna from shallow to deep water is not as marked as in the megafauna and macrofauna. The fact that it does occur may be related to

Table 4. Number of species in the principal macrofauna taxa that are confined to a single faunal zone. The percentage of each group so confined given in last column. Numbers in parentheses following taxa show the species that occur in two or more zones.

| Taxa | | Shelf/Slope Transition | Archibenthal Zone | | Upper Abyssal Zone | | Mesoabyssal Zones | Percent of Group Confined to Zones |
|---|---|---|---|---|---|---|---|---|
| | | No. of Species | No. of Species | % Above 1000 m | No. of Species | % Below 1000 m | No. of Species | |
| Porifera | ( 7) | 0 | 3 | 12 | 13 | 88 | 8 | 77 |
| Coelenterata | ( 5) | 4 | 3 | 64 | 4 | 36 | 0 | 69 |
| Polychaeta | (170) | 51 | 83 | 88 | 11 | 12 | 7 | 47 |
| Gastropoda | ( 7) | 10 | 5 | 88 | 2 | 12 | 0 | 71 |
| Bivalvia | ( 35) | 4 | 1 | 36 | 5 | 64 | 4 | 58 |
| Scaphopoda | ( 6) | 0 | 0 | 0 | 3 | 100 | 1 | 67 |
| Myodocopa | ( 8) | 1 | 5 | 86 | 1 | 14 | 0 | 47 |
| Cumacea | ( 25) | 3 | 12 | 50 | 13 | 50 | 2 | 55 |
| Tanaidacea | ( 74) | 5 | 27 | 44 | 25 | 56 | 16 | 50 |
| Isopoda | ( 65) | 5 | 8 | 37 | 19 | 63 | 3 | 35 |
| Amphipoda | ( 34) | 5 | 15 | 71 | 7 | 29 | 1 | 45 |
| Sipuncula | ( 11) | 11 | 9 | 77 | 6 | 23 | 0 | 70 |
| Bryozoa | ( 16) | 12 | 21 | 61 | 14 | 39 | 7 | 77 |
| Brachiopoda | ( 1) | 0 | 0 | 0 | 1 | 100 | 0 | 50 |
| Asidiacea | ( 3) | 0 | 0 | 0 | 5 | 100 | 2 | 70 |
| Asteroidea | ( 0) | 1 | 0 | 50 | 1 | 58 | 0 | 100 |
| Ophiuroidea | ( 7) | 3 | 3 | 67 | 2 | 33 | 1 | 56 |
| Echinoidea | ( 2) | 0 | 0 | 0 | 0 | 100 | 1 | 50 |
| Holothuroidea | ( 4) | 0 | 0 | 0 | 5 | 100 | 0 | 56 |
| Crinoidea | ( 0) | 0 | 0 | 0 | 2 | 100 | 0 | 100 |
| TOTALS | | 115 | 195 | | 139 | | 53 | $\bar{x}$ 65 |

Table 5. Comparison of meiofaunal densities derived from sampling the Eastern, Western, and Central Transects during Cruises I, II, and III. Note that the stations of Cruise III are arranged in order of increasing depth (see bottom line).

Meiofaunal Densities (No./10 cm² from top 5 cm of core) Transect and Cruise

| Taxon | Cruise II Stations Only (April 1984) West Transect 1 | 2 | 3 | 4 | 5 | East Transect 1 | 2 | 3 | 4 | 5 | Central Transect 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nematoda | 165 | 96 | 107 | 68 | 65 | 122 | 108 | 116 | 95 | 112 | 483 | 254 | 229 | 204 | 145 |
| Foraminifera | 23 | 7 | 7 | 2 | 5 | 13 | 8 | 6 | 6 | 12 | 422 | 224 | 252 | 241 | 56 |
| Harpacticoida | 85 | 35 | 48 | 32 | 26 | 28 | 43 | 41 | 36 | 40 | 109 | 109 | 88 | 69 | 41 |
| Polychaeta | 15 | 6 | 9 | 6 | 3 | 9 | 11 | 12 | 8 | 4 | 30 | 30 | 14 | 12 | 4 |
| Ostracoda | 5 | 6 | 4 | 3 | 4 | 6 | 3 | 4 | 6 | 4 | 11 | 12 | 11 | 7 | 4 |
| Kinorhyncha | 7 | 0.5 | 1 | 1 | 2 | 3 | 0.5 | 2 | 1 | 1 | 16 | 2 | 5 | 3 | 2 |
| Isopoda | 1 | 0.3 | 0.2 | 1 | 0.2 | 1 | 0.2 | 1 | 0.3 | 0.4 | 3 | 2 | 2 | 1 | 0.3 |
| Bivalvia | 1 | 0.2 | 0.4 | 1 | 1 | 1 | 0.3 | 1 | 0.3 | 0 | 1 | 1 | 1 | 1 | 0.4 |
| Tanaidacea | 1 | 0.3 | 0.4 | 0.2 | 0 | 0.2 | 0 | 0.2 | 0.1 | 1 | 2 | 0.3 | 1 | 0.3 | 0.2 |
| Halacarida | 3 | 1 | 0.4 | 0.2 | 0.2 | 0.2 | 1 | 0.3 | 0 | 1 | 0.4 | 0.3 | 0 | 0.3 | 0 |
| Cyclopoida | 3 | 2 | 0 | 0 | 0.3 | 0 | 1 | 0.2 | 1 | 1 | 0.2 | 0 | 0 | 0.3 | 0.1 |
| Loricifera | 1 | 0.2 | 0.2 | 0 | 0 | 0.2 | 0.3 | 1.4 | 1 | 0 | 0 | 0 | 0.1 | 1.4 | 0.3 |
| Sipuncula | 1 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0.1 | 0 | 0.4 | 0.4 | 1 | 0 | 0 |
| Gastropoda | 1 | 0 | 0.2 | 0.2 | 0 | 0 | 0.2 | 0 | 0.1 | 0 | 0.3 | 0 | 0.2 | 1 | 0.2 |
| Tardigrada | 0.2 | 0.2 | 0 | 1 | 1 | 0 | 0.3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| Nemertinea | 2 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.1 | 0 | 0 |
| Aplacophora | 0.2 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0.3 | 0.1 | 0.1 | 0.3 | 0 |
| Priapulida | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.4 |
| Bryozoa | 1 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Scaphopoda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 |
| Gastrotricha | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 |
| Nauplii | 37 | 22 | 17 | 18 | 17 | 15 | 21 | 20 | 13 | 21 | 60 | 43 | 47 | 42 | 20 |
| Station Total | 353 | 177 | 165 | 134 | 125 | 199 | 198 | 206 | 168 | 198 | 1139 | 679 | 652 | 584 | 274 |
| Depth (m) | 355 | 604 | 854 | 1410 | 2497 | 352 | 627 | 846 | 1353 | 2826 | 353 | 600 | 838 | 1390 | 2389 |

| Taxon | Central Transect Only Cruise I (Nov. 1983) 1 | 2 | 3 | 4 | 5 | Cruise III (Nov. 1984) 1 | 6 | 2 | 3 | 7 | 8 | 9 | 4 | 11 | 5 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nematoda | 275 | 269 | 219 | 166 | 196 | 291 | 319 | 232 | 138 | 333 | 96 | 79 | 212 | 103 | 206 | 124 |
| Foraminifera | 59 | 30 | 29 | 15 | 14 | 133 | 314 | 62 | 102 | 119 | 94 | 147 | 163 | 106 | 51 | 44 |
| Harpacticoida | 114 | 130 | 94 | 67 | 48 | 83 | 90 | 100 | 71 | 87 | 59 | 58 | 67 | 43 | 52 | 31 |
| Polychaeta | 17 | 7 | 5 | 6 | 3 | 44 | 46 | 18 | 13 | 52 | 12 | 12 | 12 | 7 | 6 | 5 |
| Ostracoda | 9 | 11 | 8 | 5 | 4 | 9 | 11 | 13 | 10 | 14 | 10 | 8 | 14 | 6 | 4 | 9 |
| Kinorhyncha | 9 | 5 | 4 | 2 | 2 | 7 | 5 | 3 | 3 | 3 | 2 | 1 | 2 | 1 | 3 | 3 |
| Isopoda | 0.2 | 0.1 | 0.1 | 1 | 0 | 0.4 | 1 | 1 | 0.3 | 1 | 0.4 | 0.2 | 0.4 | 0.4 | 0.3 | 0.1 |
| Bivalvia | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.4 | 1 | 3 | 2 | 2 | 1 | 1 | 1 | 1 |
| Tanaidacea | 1 | 0.2 | 0 | 0 | 0 | 3 | 1 | 0.3 | 1 | 2 | 0.4 | 0.3 | 0.2 | 0 | 0.4 | 1 |
| Halacarida | 0 | 0.1 | 0.1 | 0.3 | 1 | 1 | 1 | 0.4 | 0.2 | 0.3 | 0 | 0.2 | 1 | 0.4 | 0.2 | 0.4 |
| Cyclopoida | 0 | 0 | 0 | 0 | 0 | 0.4 | 1 | 1 | 1 | 1 | 1 | 0.4 | 1 | 1 | 0.3 | 0.1 |
| Loricifera | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 1 | 0.3 | 0.3 | 1 | 1 | 0.4 | 0.4 |
| Sipuncula | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.1 | 0.1 | 0 | 0 |
| Gastropoda | 0.3 | 0 | 0.1 | 0 | 0 | 1 | 5 | 0 | 0 | 1 | 1 | 0.2 | 1 | 1 | 0.1 | 0.3 |
| Tardigrada | 0 | 0.1 | 0.1 | 0 | 0.1 | 0 | 0 | 0.3 | 0 | 1 | 0.1 | 0 | 0 | 0.3 | 0 | 0.1 |
| Nemertinea | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 |
| Aplacophora | 0.1 | 0.4 | 0.1 | 0 | 0 | 1 | 0.2 | 0.2 | 0.4 | 2 | 0 | 0.3 | 0 | 0 | 0.2 | 0 |
| Priapulida | 0 | 0 | 0 | 0 | 0.2 | 0.1 | 0 | 0 | 0 | 0 | 0.1 | 0.2 | 0 | 0 | 0 | 0.1 |
| Bryozoa | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.3 | 0.1 | 0.1 |
| Scaphopoda | 0.1 | 0 | 0 | 0.2 | 0 | 0.1 | 1 | 0 | 0.1 | 0.3 | 0.3 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 |
| Gastrotricha | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0.1 | 0.1 | 0 |
| Nauplii | 33 | 37 | 34 | 21 | 25 | 33 | 55 | 47 | 33 | 45 | 34 | 31 | 49 | 38 | 44 | 27 |
| Station Total | 519 | 491 | 395 | 285 | 294 | 608 | 842 | 479 | 374 | 666 | 313 | 340 | 525 | 310 | 370 | 247 |
| Depth (m) | 363 | 615 | 852 | 1381 | 2474 | 357 | 492 | 633 | 883 | 1020 | 1192 | 1429 | 1477 | 2105 | 2518 | 2943 |

increases in predation pressure upon the meiofauna as a food source for either macrofauna and some megafauna or both.

## BENTHIC PHOTOGRAPHY

The present report on results of the benthic photographic effort is limited to 15 stations of Cruise II which were distributed among the three sampling transects.

### LEBENSSPUREN

The term lebensspuren generally applies to any manifestation (tracks, grooves, ridges, etc.) in the sediments of the presence and activities of living forms.

The Central Transect showed the lowest density of 6.4 lebensspuren features per $m^2$ among the three transects. The Western and Eastern Transects were about equal with 8.4 and 8.0 features per $m^2$, respectively. Obviously an important aim of this work is to associate a lebensspuren feature with the specific type or species of animal that made it.

Although it is almost an impossibility to assign an age to some lebensspuren features, there are some destructive processes that may easily shorten their longevity. Among these are bottom currents, accumulation of sediments, slumping, and bioturbation. The latter two appear to be the most important on the slope of the northern Gulf of Mexico. However, one may note in passing that there are some self-destructive factors at work, among them the degradation of sea cucumber fecal pellets as the organic matter holding them together is decomposed.

One great advantage of benthic photography in general is simply that it may detect species of animals in a given environment that are missed entirely by trawling. A case in point is the high density of the sea cucumber *Scotoplanes* sp. at Station C4 (Cruise II), estimated to be 6150 individuals per ha from photographs, yet none were trawled at that or any other station.

A total of 437 animals were enumerated from digitized photographs taken at the 15 Cruise II stations. The principal animal types identified, some to species level, were penaeid and caridean shrimps, brachyuran crabs, polychelid lobsterettes, galatheids or so-called rock crabs, sea cucumbers, and fish. There is good evidence that benthic photography is very likely a better method of estimating the density of some megafaunal species than is the technique of trawling as generally employed.

## DISTRIBUTION OF LAMELLIBRACHIA AND VESICOMYIDAE IN THE NORTHERN GULF OF MEXICO

Biological communities dependent upon chemosynthetic nutritive processes are known from hydrothermal vent sites located at various places in the Pacific Ocean. It has been reported that some of the megafauna involved in these communities possess internal symbionts that fix carbon by oxidizing sulfides. Similar communities have since been found in several other areas, among them being a cold sulfide seep at the base of the Florida Escarpment in the Gulf of Mexico, and from a petroleum seep in the central Gulf. Prominent vent and seep megafauna include vestimentiferan tubeworms of the genera *Riftia*, *Escarpia*, and *Lamellibrachia*, and vesicomyid clams of the genera *Calyptogena* and *Vesicomya*.

LGL photographic observations of chemosynthetic tubeworms and clams in the northern Gulf of Mexico show them to be relatively uncommon in overall occurrence, but abundant where they are found. Photographs have shown the presence of chemosynthetic tubeworms and clams in soft sediments at two suspected hydrocarbon seep sites upon the emanations from which they presumably are dependent. Tubeworms identified as *Lamellibrachia* sp. in the photographs appear to occur as scattered, random aggregates some 1000 m in length. The clams on the other hand (*Vesicomya* and *Calyptogena*) were seen to occur in two densely clustered aggregates, each about 150 m in length. The co-occurrence of live individuals amidst a scatter of dead shells suggests a community several generations in age. The different distributions of tubeworms and clams deduced from the LGL photographs suggest that the probabilities of collecting by trawl tubeworms are somewhat greater than for clams.

## LITERATURE CITED

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.